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ASSESSMENT OF DIAPHRAGMATIC DYSFUNCTION BY USG IN PROLONGED MECHANICALLY VENTILATED PATIENTS IN ICU

Anaesthesiology

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ABSTRACT

Background: Diaphragm is the primary muscle of respiration. Its dysfunction is characterized by decrease of diaphragm thickness and inadequate diaphragmatic contractility. **Aim:** To Assess the association of diaphragmatic dysfunction with length/duration of mechanical ventilation. **Methods:** It's a prospective observational study. The Ultrasound measurement for thickness fraction and excursion was performed with in 24 hours of start of MV for the selected included patient and the subsequent recording performed when patient takes 50% spontaneous breath on SIMV mode, the next recording done when patient shifted on CPAP mode and finally when patient discontinued from mechanical ventilation .The Amplitude of excursion measured on the vertical axis of the tracing from the Baseline to the point of maximum height of inspiration on the graph. **Observation And Result:** In the present study, the mean total days on mechanical ventilation were significantly higher in failure weaning (18.62±4.6) than in successful weaning (8.46±2.1) (p=0.001). Most of the cases were between 16 to 20 days on ventilation in the failure group whereas 92.9% cases of in the successful group were on ventilators for 7 to 10 days (p<0.05).the patients who have more days on mechanical ventilation has significantly lower DE and DTF. **Conclusion:** In patients receiving extended mechanical ventilation, the diaphragm's function as determined by ultrasonography can be utilized to predict the result of weaning by measuring the diaphragmatic thickness fraction and diaphragmatic excursion.

KEYWORDS

Diaphragm, Ultrasonography, Diaphragmatic dysfunction, Mechanical ventilation, Weaning

INTRODUCTION

Background Of The Study

The goals of mechanical ventilation (MV) are to maintain proper gas exchange and to replace the respiratory muscles, which may become overworked in cases of acute respiratory failure, either fully or partially.

Diaphragmatic dysfunction can arise either during the initial hospital stay or subsequent stays in the majority of intensive care unit (ICU) patients (80%).[2] The pathogenesis of VIDD is comparable to that of ventilator-induced lung injury (VILI), which is marked by elevated oxidative stress and widespread inflammation, both of which eventually result in poor gas exchange.[3]

Weaning off of MV can be difficult for a variety of reasons, including developed weakness, malnourishment, disorders of the neurological system, heart failure, infections, and other illnesses.[4,5] Diaphragm weakness, which is frequently observed in patients receiving MV and may have a role in the weaning failure, is becoming more well recognized.[6,7] Diaphragmatic dysfunction (DD) has been identified as a prevalent cause of weaning failure in the last several years.[8,9]

Numerous methods for assessing diaphragm function have been studied in the past, including trans-diaphragmatic pressure measurement, phrenic nerve stimulation, fluoroscopy, and dynamic magnetic resonance imaging. Unfortunately, these methods' invasiveness,

As a result, ultrasonography is a useful tool for the early identification and assessment of acquired weakness in the intensive care unit (ICU).

The diaphragmatic excursion (DE) and diaphragm thickening fraction (DTF) are the two diaphragm sonographic predictors that have been proposed. In the anterior subcostal view, a lower frequency curvilinear probe (a 4 MHz probe) is used to assess the DE of supine individuals. Measurements were taken in the M mode while sniffing and breathing normally, from the moment of greatest excursion to the baseline.

The diaphragm is visible when the probe is positioned between the anterior and mid-axillary lines, roughly perpendicular to the chest wall, in the vicinity of eight to ten ribs. The hyperechoic pleura and peritoneum are separated by the hypoechoic diaphragm.[10]

According to recent research, diaphragm dysfunction commonly plays a role in weaning failure[11,12] and when one is released off mechanical ventilation, it is linked to a bad prognosis.[13,14]

Need Of The Study

Prolonged mechanical ventilation (MV) is a common intervention in critical care settings, essential for patients who are unable to maintain adequate spontaneous respiration due to various medical conditions. Diaphragmatic dysfunction is frequently observed in patients undergoing prolonged MV, yet it often remains underdiagnosed due to the lack of standardized and easily accessible diagnostic methods. Successful weaning from MV is critically dependent on the functional status of the diaphragm. Diaphragmatic dysfunction can significantly delay the weaning process, increasing the risk of ventilator-associated complications.

Ultrasonography (USG) has emerged as a non-invasive, bedside diagnostic tool that offers real-time assessment of diaphragmatic structure and function. It provides several advantages over traditional methods.USG allows for dynamic evaluation of diaphragmatic motion, thickness, and contractility, providing immediate insights into diaphragmatic function.

The Aim of study was to assess the association of diaphragmatic dysfunction with length/duration of mechanical ventilation. Objectives were to Predict the outcome of weaning from mechanical ventilation in the intensive care unit with the help of USG-guided diaphragmatic excursion and diaphragmatic thickness fraction and estimate extubation success with the help of USG guide diaphragm muscle thickness fraction and diaphragmatic excursion.

METHODS

This prospective observational study was conducted in the Department of Anaesthesia at GSVM Medical College and associated LLRH Kanpur over 18 months from January 2023 to June 2024.Approval was obtained from the institutional ethical committee (ethics committee, GSVM Medical College, Kanpur Ref no: EC/BMHR/2022/154, Dated 31-12-2022).we included 41 patient who fullfill inclusion criteria and whose attendant or patient gave valid and informed consent and presumed to mechanically ventilate for a prolonged period greater than 7 days. Inclusion Criteria were Patients of both sex aged between 18 and 75 year**,** Patients presumed to mechanically ventilate for a prolonged period greater than 7 days, Resolution of primary pathology requiring mechanical ventilation, Patients who are ready to wean (RSBI<105 breath/min/L, MV<10-15, RR <35, Fio2<40%, PaO2/FiO2>200), Patients who are hemodynamically stable during

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minimal or no vasopressor support. Exclusion Criteria were Patient with a neuromuscular disorder, cardiogenic pulmonary oedema, Pregnant females in the second and third trimesters ,Patient with intra-abdominal pathology like Tense ascites, pre and post-perforation peritonitis, acute severe pancreatitis, and solid organ malignancy, Hemodynamically unstable patients, Patients on continued paralytics and heavy sedation are needed during mechanical ventilation, Patient who needs prolonged Anticipated controlled mechanical ventilation, Obese patient with BMR>35 kg/m^2. In this study Baseline diaphragmatic thickness was measured on ICU admission for all patients before mechanical ventilation (MV). Ultrasound measurements for thickness fraction and excursion were performed within 24 hours of the start of MV for the included patients. Subsequent recordings were performed when patients took 50% spontaneous breaths on SIMV mode when patients were shifted to CPAP mode, and when patients were discontinued from mechanical ventilation. From the baseline to the point of greatest inspiration height, the excursion's amplitude was measured along the vertical axis of the trace. The diaphragmatic excursion was measured with a lower frequency curvilinear probe (4 MHz) in the anterior sub-costal view. The transducer was placed between the midclavicular and anterior sub-costal views, aimed dorsally, cranially, and medially to see the right diaphragm's posterior third, around 5 cm lateral to the inferior vena cava foramen. Measurements were taken in M mode while sniffing and breathing normally, from the moment of greatest excursion to the baseline. Measuring from the maximum to the lowest point of excursion, deep breathing was used.

Using a high-frequency 7-11 MHz ultrasound linear transducer in M mode, diaphragmatic thickness was measured at both ends of maximal inspiration (total lung capacity) and maximal expiration (residual volume). The zone of apposition is the region where the diaphragm attaches to the rib cage. Six consecutive maximum breaths were performed to generate diaphragmatic ultrasonography readings, and the average values were used for analysis. Diaphragm thickness was measured from the middle of the pleural line to the middle of the peritoneal line. The diaphragmatic thickening fraction (DTF) was calculated as a percentage using the formula:

DTF=

$$\frac{(\text{Thickness at end inspiration} - \text{Thickness at end-expiration})\times 100}{(\text{Thickness at end-expiration})}$$

Ethical Consideration

Informed and written consent (in the language best understood by the patients or attendant) was obtained from each subject before data collection. Only volunteers were included, and their data were kept confidential. The study did not impose any burden on the subjects or the institute, thus justifying its ethical basis. The study was approved by the Institutional Ethical Committee.

OBSERVATION AND RESULT

- The mean age (year) of the patients was 38.24±15.2 (range 18-70 years).
- Out of the 41 patients, 25 (61.0%) were male, while 16 (39.0%) were female.
- The average weight was 59.93 kg with a standard deviation of 5.8. The mean height was 1.61 meters with a standard deviation of 0.61. The average BMI was 22.35 kg/m² with a standard deviation of 1.57.
- Out of 41 patients, 13 (31.7%) experienced failure in weaning from mechanical ventilation, while 28 (68.3%) successfully weaning.
- The mean age of patients who failed weaning was 40.0 years with a standard deviation of 19.6, while the mean age of those who succeeded was 37.43 years with a standard deviation of 13.0, with no significant difference (p=0.621).
- Among the 13 patients who experienced failure in weaning, 9 (69.2%) were male and 4 (30.8%) were female. In contrast, of the 28 patients who successfully weaned, 16 (57.1%) were male and 12 (42.9%) were female. The difference in gender distribution between the failure and successful weaning groups was not statistically significant (p=0.460).
- The mean height for the failure group was 1.62 meters with a standard deviation of 0.05, compared to 1.60 meters with a standard deviation of 0.06 for the successful group, also not significantly different (p=0.433). The average BMI was 22.2 kg/m² with a standard deviation of 1.3 for the failure group and 22.4 kg/m² with a standard deviation of 1.6 for the successful group, with no significant difference (p=0.795).
- None of the patients in either group had prolonged use of heavy sedation and paralytics or prolonged steroid therapy. Among the 13 patients who failed weaning, 8 (61.5%) were on total parenteral nutrition (TPN), compared to 16 (57.1%) of the 28 successfully weaned patients.
- None of the patients in either group required vasopressor support. All patients had normal ECG and chest X-ray results. Additionally, all patients had a PaO2/FIO2 ratio greater than 200.
- Among the 13 patients who failed weaning, 1 (7.7%) was on mechanical ventilation for 7-10 days, 2 (15.4%) for 11-15 days, 6 (46.2%) for 16-20 days, and 4 (30.8%) for more than 20 days. In contrast, among the 28 successfully weaned patients, 26 (92.9%) were on mechanical ventilation for 7-10 days, 1 (3.6%) for 11-15 days, and 1 (3.6%) for 16-20 days, with none exceeding 20 days.
- The mean duration of mechanical ventilation was significantly longer for the failure group at 18.62 days with a standard deviation of 4.6, compared to 8.46 days with a standard deviation of 2.1 for the successful group (p<0.001).

Table : Distribution Of The Studied Patients Based On The Total Number Of Days On Mechanical Ventilation In Failure & Successful Weaning Groups

Total no days on Mechanical ventilation		Failure weaning (n=13)	Successful weaning (n=28)	p-value
No. of days	7-10 days	1 (7.7%)	26 (92.9%)	<0.001
	11-15 days	2 (15.4%)	1 (3.6%)	
	16-20 days	6 (46.2%)	1 (3.6%)	
	>20 days	4 (30.8%)	0 (0.0%)	
Mean±SD		18.62±4.6	8.46±2.1	<0.001

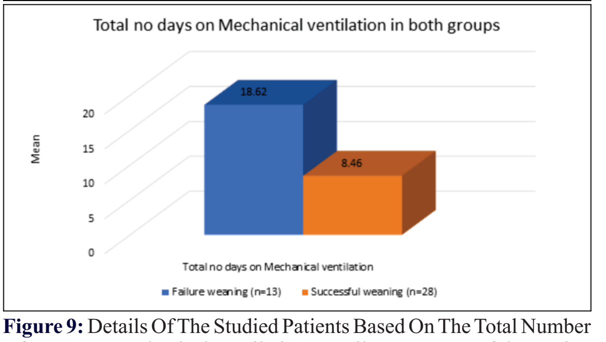

Figure 9: Details Of The Studied Patients Based On The Total Number Of Days On Mechanical Ventilation In Failure & Successful Weaning Groups

- At admission, the diaphragmatic thickness fraction was significantly lower in the failure weaning group (83.54±4.0%) compared to the successful weaning group (86.43±4.1%; p=0.044).
- During SIMV mode with 50% spontaneous breath, the failure weaning group showed markedly lower diaphragmatic thickness (38.0±4.4%) compared to the successful weaning group (72.4±7.4%; p<0.001), which persisted during transitions to CPAP mode and discontinuation from mechanical ventilation (p<0.001 for both).
- The diaphragmatic excursion did not differ significantly between the groups at admission (1.29±0.08 cm vs. 1.29±0.08 cm; p=0.889), but significant differences were observed during SIMV mode with spontaneous breath (0.93±0.13 cm vs. 1.20±0.07 cm; p<0.001) and subsequent transitions (p<0.001 for both).

Table 13: Details Of The Studied Patients Based On Diaphragmatic Thickness & Diaphragmatic Excursion In Failure & Successful Weaning Groups

Variables	Failure weaning (n=13) (Mean±SD)	Successful weaning (n=28) (Mean±SD)	P value
Diaphragmatic thickness fraction at time of admission in %	83.54±4.0	86.43±4.1	0.044

Diaphragmatic thickness fraction at the time when a patient is on SIMV mode and takes 50% spontaneous breath	38.0±4.4	72.4±7.4	<0.001
Diaphragmatic thickness fraction when patient shifts from SIMV to CPAP mode	28.08±3.2	66.43±7.1	<0.001
Diaphragmatic thickness fraction at the time when the patient discontinues mechanical ventilation	25.69±3.0	64.68±7.8	<0.001
Diaphragmatic Excursion at time of admission in cm	1.29±0.08	1.29±0.08	0.889
Diaphragmatic Excursion at the time when the patient is on SIMV mode and takes 50% spontaneous breath	0.93±0.13	1.20±0.07	<0.001
Diaphragmatic Excursion when the patient shifts from SIMV to CPAP mode	0.77±0.09	1.16±0.06	<0.001
Diaphragmatic Excursion at the time when the patient discontinues mechanical ventilation	0.77±0.09	1.16±0.05	<0.001

Table 14: Receiver Operating Characteristics Curve (ROC) For Diaphragmatic Thickness Fraction To Differentiate Between Successful Weaning And Failure Weaning

Parameter	Accuracy	Cut off point	Sensitivity	Specificity
Diaphragmatic thickness fraction at time of admission in %	72.3%	83.0%	89.3%	38.5%
Diaphragmatic thickness fraction at the time when a patient is on SIMV mode and takes 50% spontaneous breath	100.0%	51.0%	100.0%	100.0%
Diaphragmatic thickness fraction when the patient shifts from SIMV to CPAP mode	100.0%	44.0%	100.0%	100.0%
Diaphragmatic thickness fraction at the time when the patient discontinues mechanical ventilation	100.0%	38.5%	100.0%	100.0%

Table 15: Receiver Operating Characteristics Curve (ROC) For Diaphragmatic Excursion To Differentiate Between Successful Weaning And Failure Weaning

Parameter	Accuracy	Cut off point	Sensitivity	Specificity
Diaphragmatic Excursion at time of admission in cm	51.9%	1.25	67.9%	38.5%
Diaphragmatic Excursion at the time when a patient is on SIMV mode and takes 50% spontaneous breath	96.2%	1.15	75.0%	100.0%
Diaphragmatic Excursion when the patient shifts from SIMV to CPAP mode	100.0%	1.0	100.0%	100.0%
Diaphragmatic Excursion at the time when the patient discontinues mechanical ventilation	100.0%	1.0	100.0%	100.0%

DISCUSSION

The main breathing muscle is the diaphragm. A reduction in diaphragm thickness and insufficient diaphragmatic contractility are signs of its malfunction. Clinically speaking, diaphragmatic dysfunction is a factor in difficult weaning or even failure to wean ICU patients off of mechanical breathing. Overall, the findings suggest that up to 25.0% of ICU patients on mechanical ventilation may experience weaning failure.

This research was conducted for patients requiring extended mechanical ventilation who were scheduled to discontinue mechanical ventilation, carrying out several earlier studies on the use of the US evaluation of the diaphragm as a tool to predict weaning from mechanical ventilation. The present study was done to assess Diaphragmatic dysfunction by USG in prolonged mechanically ventilated patients in the ICU. The study was conducted on 41 mechanically ventilated patients with a mean age of 38.24±15.2 years and male predominance (16 females). In the present study, the outcomes of the patients revealed that out of 41 patients, 13 (31.7%) experienced failure in weaning from mechanical ventilation, while 28 (68.3%) successfully weaning. Based on the distribution of the studied patients based on age in failure & successful weaning groups there was no significant difference observed with age, gender, weight, height, BMI, and hemodynamic parameters ($p>0.05$). In the present study, the mean total days on mechanical ventilation were significantly higher in failure weaning (18.62±4.6) than in successful weaning (8.46±2.1) ($p=0.001$). Most of the cases were between 16 to 20 days on ventilation in the failure group whereas 92.9% cases of in the successful group were on ventilators for 7 to 10 days ($p<0.05$). In the present study, at admission, the diaphragmatic thickness fraction had an accuracy of 72.3%, with a sensitivity of 89.3% and specificity of 38.5% at a cutoff of 83.0%. During SIMV mode with 50.0% spontaneous breaths, accuracy improved to 100.0%, with both sensitivity and specificity reaching 100.0% using a cutoff of 51.0%. This perfect performance was maintained during the transition from SIMV to CPAP mode and when discontinuing mechanical ventilation, with cutoffs of 44.0% and 38.5%, respectively. Whereas diaphragmatic excursion at admission had an accuracy of 51.9%, with sensitivity of 67.9% and specificity of 38.5% at a cutoff of 1.25 cm. On SIMV mode with 50.0% spontaneous breaths, accuracy increased to 96.2%, with sensitivity at 75.0% and specificity at 100% using a cutoff of 1.15 cm. Similarly, during the transition from SIMV to CPAP mode and when discontinuing mechanical ventilation, diaphragmatic excursion achieved 100% accuracy, sensitivity, and specificity with a cutoff of 1.0 cm in both instances, indicating perfect differentiation between successful and failed weaning.

CONCLUSION

In patients receiving extended mechanical ventilation, the diaphragm's function as determined by ultrasonography can be utilized to predict the result of weaning by measuring the diaphragmatic thickness fraction and diaphragmatic excursion. A straightforward technique for assessing DE and the thickness of the muscle in the zone of apposition is diaphragm ultrasound. This method is safe, extremely practicable, and reproducible on the same patients. Evaluation of DTF and DE using diaphragm ultrasonography in M-mode is a novel, simple-to-obtain weaning index that might be implemented as a bedside technique in clinical practice if more research validates.

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